

**BUREAU OF ENVIRONMENTAL REMEDIATION/REMEDIAL SECTION
GUIDANCE
INVESTIGATION AND REMEDIATION OF SALT(CHLORIDE)-
IMPACTED SOIL AND GROUND WATER**

BER POLICY # BER-RS-13A

DATE: March 2004

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1.0 Introduction

This policy provides information on methods for investigating, evaluating and remediating soil and ground water contaminated with brine or salt. For the purposes of this policy, the terms brine, salt, and chloride may be used interchangeably.

This policy addresses primarily point source salt contamination of soil and ground water. Accumulation of soluble salts in soil can occur naturally in arid and semi-arid regions, or as a result of a release of brine or salt into the environment. Common soluble salts present in the environment include chlorides and sulfates of calcium, magnesium, sodium and potassium. Salt contamination is not normally a hazard to human health; however, it can cause adverse and long lasting environmental impacts to soil and ground water resources because chlorides are highly soluble, do not adsorb onto soil particles, do not degrade, and generally inhibit biological processes. Releases of salt onto the ground can damage soils by destroying the soil structure and permeability. The presence of high concentrations of soluble salts can inhibit seed germination and a plant's ability to uptake water. Salt-contaminated soil in the near surface can lose its ability to support either agricultural crops, native grasses, or other vegetation if salt levels are high enough, potentially contributing to surface erosion.

If vertical migration from the near surface soil through the vadose zone to the underlying water table occurs and chloride impacts ground water, degradation of the aquifer can result in long-term loss of value as a source for public or private drinking water supply, irrigation, or industrial purposes.

2.0 Shallow Soil

One of the goals for remediation of soil contaminated with brine or salt is to restore the ability of the soil to support vegetation. Three criteria are important for characterizing salt contamination for the purpose of evaluating the soil for its ability to support vegetation and identifying alternatives for soil reclamation: 1) total soluble salts (TSS or salinity); 2) sodium adsorption ratio (SAR); and 3) soil pH. TSS is measured as conductivity. SAR (Equation 1, page 6) is used to estimate the relative activity of sodium ions in exchange reactions with soil, indicating the sodium or alkali hazard to soil. Soils can be classified as saline, saline-sodic, sodic, or normal on the basis of SAR, soil pH, and TSS values as described in Table 1. The soil classification (e.g., saline or sodic) can be used to determine the most appropriate alternative for reclamation of salt-contaminated soil for the purpose of establishing vegetation. Since most plants and trees obtain the bulk of their nutrients and water from the upper 3 to 4 feet of the soil column, testing for TSS,

SAR and soil pH should be limited to the upper 4 feet of soil. Testing of the soil for these parameters may be necessary for areas that can not support vegetation or areas where the vegetation shows signs of stress. Analytical methods are identified in Section 5.0.

The cleanup level for shallow soil shall be site specific as determined by KDHE but will be based on the ability of the soil to support vegetation and will take into consideration the soil to ground water pathway as described in Section 3.0.

3.0 Soil to Ground Water Pathway

Another primary goal for soil contaminated with salt includes preventing leaching of salt constituents from the soil into an aquifer. The methodology for calculating the concentration of chloride in soil that is preventative of migration to ground water was derived from the document titled *Soil Screening Guidance: Technical Background Document*, OSWER 9355.4-17A, EPA/540/R-95/128 May 1996. To calculate this concentration of chloride, KDHE used similar assumptions and default input parameters identified in the *Risk-Based Standards for Kansas (RSK Manual)*, 3rd Version, March 1, 2003. The calculation (Equation 2) and default input parameters are shown on page 7. Using the default input parameters and the Federal secondary maximum contaminant level (SMCL) of 250 milligrams per liter (mg/L) for chloride in drinking water, the concentration of chloride in soil that is protective of ground water is 1,000 milligrams per kilogram (mg/Kg).

The default dilution attenuation factor (DAF) of 20, used in Equation 2, is based on a source area of 0.5 acres (i.e., length of the source parallel to ground water flow is 147.6 feet, assuming a square source). If the source area is larger than 0.5 acres, KDHE may determine it is appropriate to calculate a site-specific DAF. Equation 3 can be used to calculate a site-specific DAF. Calculation of a site-specific DAF requires calculation of a site-specific mixing zone depth (Equation 4). Input parameters for calculation of the DAF and mixing zone depth are identified on page 7.

At sites where the natural background concentration of chloride in ground water is greater than the SMCL of 250 mg/L, the natural background concentration in ground water may be used to calculate a site-specific concentration of chloride in soil that is protective of ground water. Section 4.0 discusses determination of the natural background concentrations in ground water. To calculate the site-specific soil to ground water concentration, the natural background concentration of chloride in ground water is substituted for the regulatory standard in Equation 2.

The site soil above the water table (i.e., vadose zone) must be adequately characterized for chloride contamination to provide data for the evaluation of the soil to groundwater pathway. While only the upper 4 feet of soil is tested to evaluate the soil's ability to support vegetation (Section 2.0), the entire soil column in the vadose zone, including the upper 4 feet, should be evaluated for the soil to ground water pathway.

4.0 Ground Water

The goal for remediation of chloride contaminated ground water is to return the aquifer to the most beneficial use, be it drinking water, irrigation, or other uses. If the concentration of chloride in an aquifer

is naturally high, the goal is to return the aquifer to natural background levels.

The remedial goal of 250 mg/L for chloride in drinking water is the Federal SMCL. The SMCL for chloride is based on the concentration at which the taste of the water becomes objectionable.

The remedial goal for chloride in water used for irrigation is 350 mg/L. The acceptable level of chloride in irrigation water is dependent on the crop. Most Kansas crops are only intermediate in their salt tolerance. Chloride tolerance of agricultural crops without loss in yield ranges from 350 mg/L to 2,800 mg/L (*Irrigation Water Quality Standard and Salinity Management*).

Background concentrations may be determined for substances that are naturally occurring such as chloride. If pre-existing data is not available or not representative of the site, the natural background conditions may be determined as part of the site characterization, with KDHE concurrence. If the natural background concentration of chloride is greater than 250 mg/L, the natural background concentration becomes the site-specific cleanup standard for ground water. Ultimately, it will be necessary to gain approval from the KDHE project manager for sampling strategies meant to characterize background environmental quality and calculation of site-specific cleanup standards.

5.0 Analytical Methods

During scoping of investigation activities, the analytical methods used for characterizing soil and ground water contamination should be discussed with the KDHE project manager. Where chloride contamination is identified or suspected, other soluble salts are likely to be present and may be important for consideration during evaluation and design of corrective actions. Soluble salts generally include: sodium, calcium, magnesium, potassium, sulfate, chloride, carbonate, and bicarbonate. The sampling and analysis plans for chloride contaminated sites may include testing the soil and water for chloride, TSS, SAR, pH, and metals or other parameters as appropriate. Standard analytical methods are identified in Table 2. Other methods may be considered for approval by the KDHE project manager.

6.0 Corrective Action Alternatives

The corrective action alternatives presented here address both soil and ground water. The list of corrective action alternatives provided below is not meant to be a complete list of the available alternatives. KDHE will review and may approve another reasonable corrective action alternative provided it is protective of the environment and adequate justification for the method is supplied.

KDHE strongly supports implementation of interim remedial measures (IRMs) as a means to achieve remedial goals more quickly and reduce the overall cost of site remediation. IRMs can consist of removal of sources of contamination in soil, provision of alternate water supplies, containment of contaminated ground water, or other appropriate action. The responsible party may implement IRMs with KDHE approval.

Corrective Action Alternatives for Soils

- **Excavation and disposal of salt-impacted soil at an approved landfill**
Disposal in a landfill may require a Special Waste Authorization. The disposal authorization and further information can be obtained through the KDHE/Bureau of Waste Management - Waste Compliance, Enforcement and Policy Section.
- **Excavation and disposal of salt-impacted soil into salt caverns**
Although there are no regulatory barriers in Kansas to cavern disposal, there are several constraints including identifying a Class III salt solution mining facility willing to take the material. Plans describing the injection procedure, spill contingencies, etc., must be submitted to the KDHE/Bureau of Water - Underground Injection Control Unit for approval.
- **Capping with an engineered, hydraulically impervious barrier**
Capping salt contaminated areas may require attaching an environmental use control (EUC) to the property title. Information about the EUC Program can be obtained by contacting the KDHE/Bureau of Environmental Remediation - Remedial Section.
- **Soil washing**
This alternative includes excavation and ex-situ treatment of the contaminated soil. Following treatment, the soil is returned to the site or used otherwise as appropriate. The process water from soil washing will require disposal by a KDHE-approved method.
- **In-situ leaching, with ground water hydraulic control and recovery**
Leaching saline soils may be applicable where certain conditions can be met including the availability of a water supply of acceptable quality, soil with adequate permeability to allow percolation of the water through the soil column, surface runoff control, and containment and recovery of leachate where ground water is a useable resource, as determined by KDHE.
- **Addition of soil amendments and in-situ leaching**
Soil chemistry must be considered and the amendment (gypsum, organic matter, etc.) must be adequately mixed with the salt-contaminated soil. This alternative may not be appropriate for deeply impacted soils. Leaching may not be appropriate for areas where drinking water or irrigation supplies may be affected.

Corrective Action Alternatives for Ground Water

- **Alternate drinking water supply**
Upon identification of a salt impact to a drinking water well the responsible party is required to immediately provide an alternate drinking water supply to the impacted receptors. Alternate supplies may include provision of bottled water, installation of a whole-house treatment system, re-drilling the well in a different location or to a non-impacted aquifer, or connection to a public water supply. Some programs, such as the Voluntary Cleanup Program, may have a more stringent definition of an alternate water supply. Provision of an alternate drinking water supply may be a component of the selected corrective action for a site.

- **Hydraulic containment with beneficial use, deep disposal, or treatment of the extracted water** Hydraulic containment will prevent further degradation of the aquifer. The extracted ground water can be treated by ion exchange or reverse osmosis technologies to remove chloride. Beneficial use of the treated water is preferred. A less desirable but valid option is to dispose of untreated water to a deep injection well. Deep disposal of untreated water will require approval of the KDHE/Bureau of Water - Underground Injection Control Unit. In some instances the KDHE/Bureau of Water may approve discharge to a stream or river under a National Pollution Discharge Elimination System (NPDES) permit.
- **No remediation approved in special circumstances**
If receptors are provided with alternate water supplies, and natural ground water quality is such that the water is not potable or useable for irrigation, the no-action alternative may be considered. Installation of a ground water monitoring well network and monitoring plan for tracking of the contamination will be necessary. Selection of the no-action alternative will require KDHE concurrence.

7.0 References

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11. United States Department of Agriculture, National Resources Conservation Service, *Plant Materials and Techniques for Brine Site Reclamation*, Plant Materials Technical Note No. 26, February 5, 2001.

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Table 1. Classification of Salt-Affected Soils

Classification	Electrical Conductivity (mmhos/cm)	Soil pH	Sodium Adsorption Ratio	Soil Physical Condition
Normal	< 4.0	< 8.3	< 13	Normal
Saline	> 4.0	< 8.5	< 13	Normal
Sodic (alkali)	< 4.0	> 8.5	> 13	Poor
Saline-sodic	> 4.0	< 8.5	> 13	Normal

Table 2. Analytical Methods for Water Samples

Parameter	Methodology	Method Identification
Sodium Adsorption Ratio (analysis of extract from water-soil slurry or water-soil saturated paste for sodium calcium and magnesium)	Atomic Absorption Inductively Coupled Plasma	Standard Methods (SM) 3111 B EPA 200.7 or SM3120 B SW-846 Method 6010B
Total Soluble Salts (TSS) (measured as conductivity)	Conductance	EPA 120.1 or SM 2510 B SW-846 Method 9050A
pH	Electrometric	SM 4500-H ⁺ B SW-846 Method 9045C
Chloride	Ion Chromatography Titrimetric Colorimetric	EPA 300.0 EPA 325.3 SM 4500-Cl-B
Alkalinity	Titrimetric Colormetric	EPA 310.1 or SM 2320 B EPA 310.2
Sulfate	Ion Chromatography Colorimetric	EPA 300.0 EPA 375.1 or 375.2

Table 3. Cleanup Goals for Chloride Impacted Sites

Parameter and Setting	Soil to Ground Water Migration Pathway	Ground Water Pathway
Chloride in a potable aquifer (drinking water) setting	1000 mg/Kg	250 mg/L
Chloride where an aquifer is used for irrigation but not as a drinking water supply	1400 mg/Kg	350 mg/L

Equation 1. Sodium Adsorption Ratio (SAR)

$SAR = \frac{[Na^+]}{\sqrt{0.5([Ca^{2+}] + [Mg^{2+}])}}$		Equation 1
Parameter	Definition (units)	

SAR	Sodium Adsorption Ratio (unitless)
[Na ⁺], [Ca ²⁺] and [Mg ²⁺]	Concentration of sodium, calcium and magnesium (milliequivalents per liter)

Equation 2. Soil to Ground Water Migration Pathway Equation

$C_t = C_w \left((K_d) + \frac{q_w + q_a H'}{r_b} \right)$			Equation 2
Parameter	Definition (units)	Default	
C _t	Screening level in soil (mg/Kg)		
C _w	target soil leachate concentration (mg/L)	Regulatory Standard X DAF	
Regulatory Standard	maximum contaminant level (mg/L)	250 (secondary MCL for chloride)	
DAF	dilution attenuation factor (unitless)	20	
H'	Dimensionless Henry's Law Constant	0	
K _d	Soil-water partition coefficient (L/kg)	0	
θ _w	Water-filled soil porosity (L _{water} /L _{soil})	0.3	
θ _a	Air-filled soil porosity (L _{air} /L _{soil})	0.13	
θ _b	Dry soil bulk density (kg/L)	1.5	

Equations 3 and 4. DAF and Mixing Zone Depth (d) Equations

$DAF = 1 + \left(\frac{K_d I}{I L} \right)$			Equation 3
$d = \left(0.0112 L^2 \right)^{0.5} + d_a \left\langle 1 - \exp \left[\frac{-L I}{K_d \theta_a} \right] \right\rangle$			Equation 4
Parameter	Definition (units)		
DAF	dilution attenuation factor (unitless)		
K	aquifer hydraulic conductivity (meters/year)		
i	hydraulic gradient (meter/meter)		
d	mixing zone depth (meters)		
I	infiltration rate (meters/year)		
L	length of source parallel to ground water flow (meters)		
d _a	saturated aquifer thickness (meters)		